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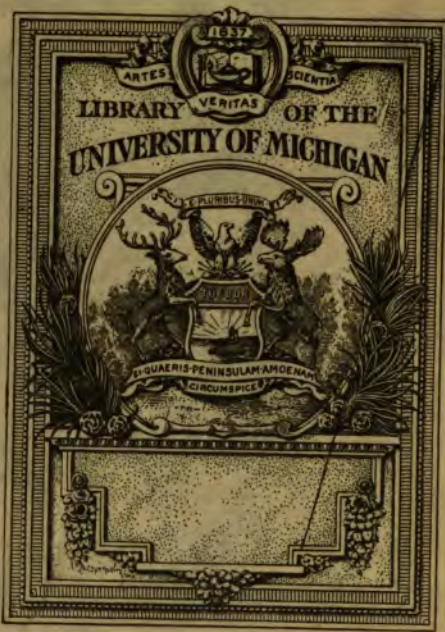
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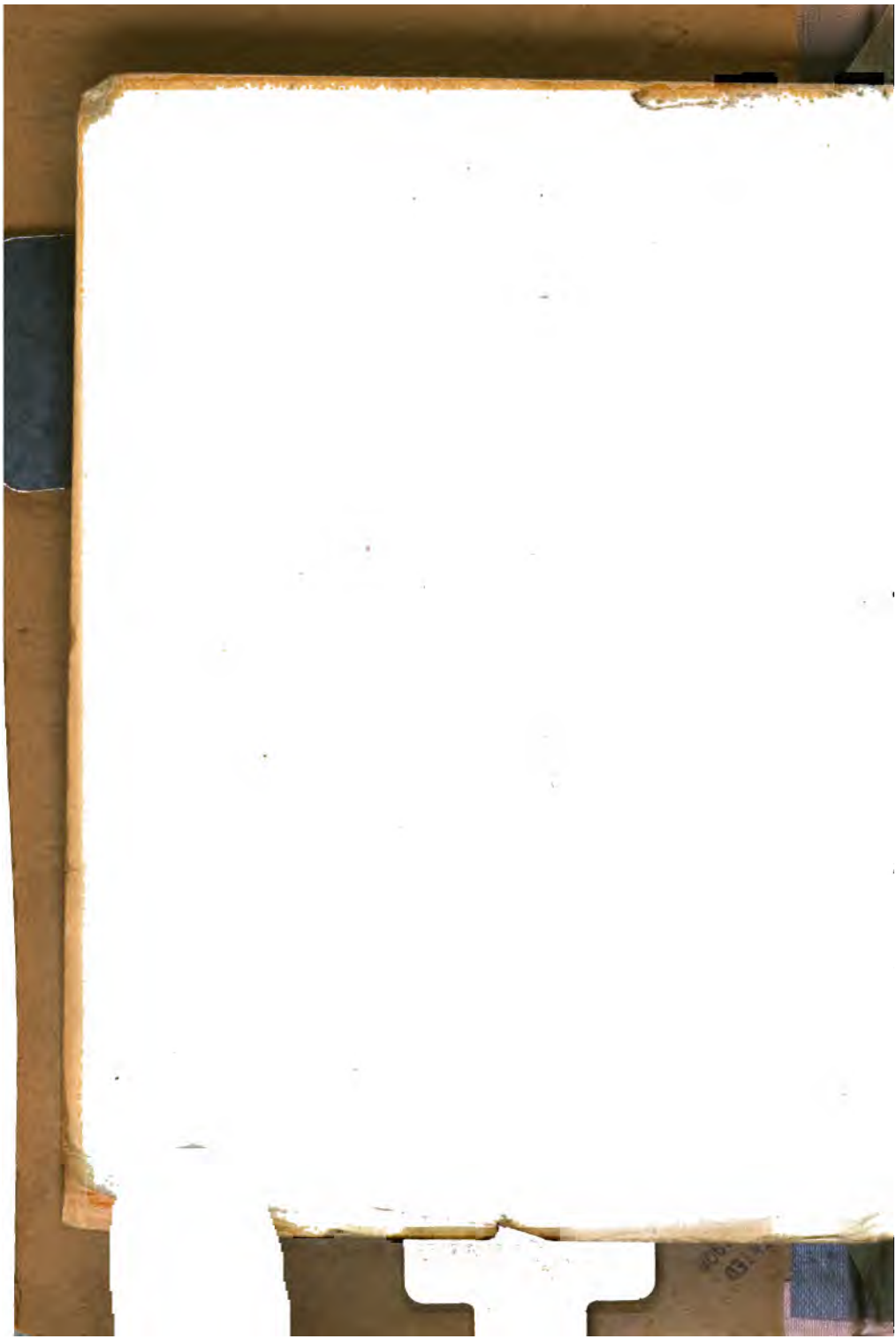
DYNAMICS OF MATTER



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AND

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2-31-08 E.T.J.

PREFACE

PART OF A LIFE WORK is outlined in the following pages. The positions are radical but well considered, having been maintained and developed during a quarter-century of science teaching. Now I fear that the central thoughts will be lost unless recroded. My subject is very dry, yet matters of every day experience are set forth in an unusual manner, to say the least. We hope to jog a little the prevailing looseness in dealing with exact science. The bald criticism of misused terms and of popular theory, in many places will not be welcome. Our only appeal is to common sense and reason. This little work will serve to introduce our new and improved method of kinetic calculation, which may appear later. The present aim has been to present a true Mechanical Analysis not found in other books.

Pontiac, Michigan, January 1, 1908.

Surrendered 10-21-37

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Dynamics of Matter

I. MASS AND WEIGHT.

Mass as a quantity depends on density and volume, and is measured in units of weight; as a material, it is capable of action and resistance.

Mass is a quantity of matter. It is wrong to call inertia or gravitation mass, since these are only properties of matter and not matter itself.

Mass weight, often determines commercial value. Shaking and pressure changes the volume of tea, hay or cotton, but not the mass nor financial worth. Mass is the sum of molecules, and is the most exact measure of matter.

Force weight, is pressure downward caused by gravitation. It is mutual attraction, earth mass being on one side. It is varied by distance from the earth's center.

A mass-pound pulls down with force-pound weight at the average earth's surface. Four thousand miles up, it would only pull a **spring balance** to a quarter; but the mass, as a pound of tea, would remain the same, and balancing scales would show this amount,—a true mass-weight for commercial purposes.

The mass of an animal would suffer no change on the surface of the moon; but a squirrel's gravity would be much less than on the earth, and if feeling well and strong in the new position, he might jump much higher, and become a flying squirrel.

Inertia depends on mass, and not on force-weight, which varies with the earth's attraction.

The primary significance of weight is the force of gravity near the earth's surface. Human experiments are limited to this region; hence common weight varies mostly with the mass and becomes its measure.

II. PULLING AND PUSHING.

Force is a pull or a push and never anything else.

An old subscriber to the **Scientific American,** asked for the force of a blow of his trip hammer weighing three tons and falling four feet.

Scientific men and engineers ought to know how to answer such a question as that, but they could not agree.

One calculated momentum; another, **vis viva**; and a third, work. Then one said "pressure and pressure alone," but had no answer to the problem. "Vulgar pretenders," tartly exclaimed a well known Doctor of Philosophy. "Force," said he, "is nothing but matter in motion." Of course

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he had no answer to the question on that ground. Philantropy and philosophy had no milk for "Ginx's Baby." The trip-hammer fell; but mathematicians did not agree as to its true force. Periodic fits of similar discussion followed each other from year to year in times that I remember. It suggested to the writer the importance of a new study of physical energy and motion.

How many of our readers can answer the "old subscriber" today? Try it. Some teachers of physics have recently enquired about the true answer.

III. INERTIA AND GRAVITATION.

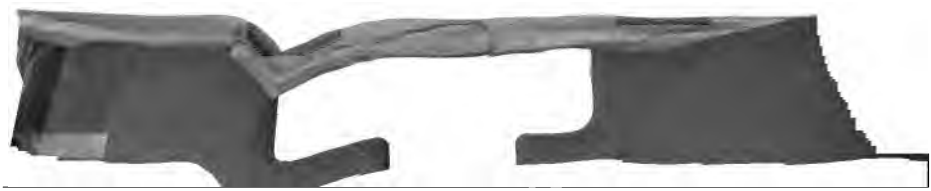
These are the universal properties of matter; and, conditions being similar, their forces are as the masses. This is a law without exception.

Inertia is that inherent energy of matter which opposes any force changing the state of motion or rest.

Striking a stone may be a painful illustration. Inertia promptly kicks back against an aggressive foot or fist.

Inertia makes matter persist in any state of motion or rest; and in movement it becomes aggressive against obstacles.

The hammer manifests no force except resistance



until it strikes. Then inertia puts aggressive force into the blow against whatever checks the hammer's progress.

In circular motion, pulling along the **radius vector,** against any central force deflecting natural straight line movement into a curve, inertia maintains a constant centrifugal force. It is static in its nature because self-repeating and unchanging except in direction. No progressive work is done, and it may be called a static condition of inertia.

Inertia is solitary in habit, and latent until aroused by motion change.

Gravitation is supposed to make every particle of matter in the Universe attract every other particle with a force inversely as the square of the distance. It is not solitary in habit, but a mutual bond, very weak between small bodies near or far, immeasurably so, but great between large masses.

When one mass is the earth and the other a smaller body near its surface, the gravitation is called gravity, and its measure weight.

In the circulation of worlds gravitation furnishes the centripetal force against the centrifugal action of inertia.

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IV. MATERIAL DISCUSSION.

Before the discovery of Gravitation and development of Chemistry, matter was called inert in a literal sense. Then it was believed to exist in a state of helpless inability as a mere passive dross, incapable of action or of exerting any force, or of putting itself in motion. All activity was supposed to come from without, or to belong to some genii, or spirits of life. It was a great discovery for Newton to see an apple fall in the true light of mutual, material self-action.

The self activity of matter is also exhibited in chemism. Conditions of temperature and affinity give license to atomic energies that instantly pull or push in chemical reactions.

Matter moves naturally and promptly when apples fall or powder explodes, without the aid of any supernatural or foreign powers once supposed to move and animate nature. Subtle energies appear to reside within the atom itself, and are called properties.

Yet much of the old philosophy remains in the heart of the world. Like lazy animals, matter seems to prefer rest to motion. This is attributed to its deadness. We say, it must be put in motion, and once moving it cannot stop. Inability in both cases.

But it is harder to start or stop heavy bodies than light ones. Have they more inability? Is the thought rational? In both cases does not matter actually resist or oppose our effort to change the state of rest or motion?

Movement was supposed to be a sort of gift or loan bestowed upon matter, and superior to matter itself. It was a borrowed life or investing element often falsely called force or energy. Aside from figurative language, though it may be a source of power, we expect to show that motion is neither life nor fundamental energy.

The ancients did not know that all bodies were really in swift motion in space, and that what we call rest on earth is only a relative term of local harmony and never absolute like Energy.

It is a fact that a man may be standing still on a swiftly flying steamer. When he walks in the cabin, we observe his motion among chairs and tables. It is the differential and local change that we call motion. Hence motion is never an absolute property of matter, but only a relative phase.

The power of motion, so called, is due to inertia. Bodies moving independently are aggressive; and like stray dogs, fight their own way. By conservatism and war, inertia forces peace and maintains a

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degree of uniformity in nature, prohibting many abrupt changes. The balance wheel is a type of its usefulness in mechanics and in nature.

Matter is full of energy as an egg is of meat. Not only inertia and gravitation belong to it, but cohesion, and elastic, electric and magnetic properties, as well as the affinities and repulsions of chemical and physical science. We can not view matter as inert in the literal sense of that term. On the contrary we find in atoms the very root of all physical energy and power.

All the energies of matter are co-operative and intelligently balanced. They carry within themselves the very highest evidence and proof of an Almighty, Designing, Creator.

V. EVOLUTION OF INERTIA.

The word **inertia** is derived from the Latin **in ars**, literally meaning want of art or ability. Its application to a certain property of matter, has been the source of much confusion and error. Writers find it hard to break away from plain derivation, hence many conflicting statements. **Inability** is not in harmmony with either **tendency** or **resistance,** nor with the word **maintain**; so the blind have led the blind even to the present hour.

Some have made a double definition, giving **vim**

to inertia in one and **passivity** in the other, as if fearing to be left on record bucking against the creed. Others, more logical, have omitted the negative side without openly disputing it. The victory of silence may be most secure. Let us illustrate by a few parrot-like quotations from school books, with others of greater strength. We might give scores of the former.

Elements de Physique. Professor Ganot.

Many editions in France, Germany and Spain. Translated into English by Atkinson, 4th edition revised Sept. 1869. Model for many American publications.

"**Inertia is a purely negative property of matter.**" How can a **property** be negative? The author adds on the same page as to railway accidents, "Where the motion of the engine is suddenly arrested, the carriages **strive** to continue the motion * * * and are shattered." This makes the negative property **strive** as if it had energy.

Applied Mechanics. Professor Rankine.

5th edition, Glasgow University, 1869. A standard work in engineering.

"**The mass or inertia** of a body, is a quantity proportional to the unbalanced force which is required in order to produce a given definite change

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in the motion of the body in a given interval of time."

The above definition treats mass and inertia as identical when they are only proportionate. Gravitation, also proportionate, would be in the same bunch. Then, the "unbalanced force" is more or less according to velocity and time, which seems to make the mass of a body a variable depending on speed. This cautious definition is evidently noncommittal; but can anything be equal or proportionate to a force easier than force itself?

Natural Philosophy for Students in College.

Denison Olmstead, 1844, Revised by Prof. Snell in 1870, and by Prof. Kimball in 1882.

"**Inertia of Matter** signifies its tendency to continue in its present condition of motion or rest. If at rest, it can not move itself; if in motion it can not stop."

Tendency denotes **strain**; but the last clause expresses inability pure and simple.

Principles of Physics for Colleges.
Prof. Silliman of Yale. 1860.

"Inertia. No particle of matter possesses within itself the power of changing its existing state of motion or rest."

Natural Philosophy. J. W. Draper, M. D. 1847.

"A mass of any kind when at rest **resists** the application of force to put it in motion, and when in motion **resists** any attempt to bring it to rest. This property is termed **Inertia.**"

This **resisting** statement was larded over in the next paragraph by the "inactive" theory. In some later works no such apology would be made. There is evidently light before us. To spare you weariness, we insert only two more quotations.

Elements of Mechanics. Prof. Merriman, Leigh University, 1905.

"If a ball is thrown by hand a **resisting force called inertia** is felt."

Elements of Physics. Carhart and Chute, University of Michigan.

"**Inertia** is that property manifested by matter in its **persistance** in whatever state of rest or motion it may happen to have, and in its **resistance** to any attempt to change that state. * * * An instance of inertia is furnished in the persistance with which a rotating object maintains its plane of rotation."

The Gyro or mono-rail car of Louis Brennan, is a fine illustration of Inertive-static action, as we view it.

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VI. VARIETY OF ACTION.

Physical energies appear to be inherent properties which enable matter to exert force. Inertia and gravitation are universal, and under like conditions act in proportion to mass. Adhesion and cohesion are variable properties. Cohesion is weak in tallow but strong in steel. Water has very little cohesion except when frozen. It adheres to any surface that can be wet. Air adheres to solids. Put wire nails into water carefully, and see the bubbles that fail to be washed off. Glue adheres with strength. Either may be elastic. In bending a spring, one side is condensed and the other expanded. With opportunity it recovers form.

Chemism is variable, having many peculiar affinities. Caloric, electric, and magnetic properties also belong to matter in a variety of ways, and give rise to material action.

Material energy as well as mental energy, may be exerted or latent. It is exerted in force but latent when not producing force.

Inertia is latent except in change of motion either in velocity or direction. A peculiar form of inertive activity is shown in the gyroscope.

Gravitation, as to force, varies inversely as the square of the distance. We suppose it never latent,

but future astronomy may disprove this idea.

Conditions of reaction determine the exertions of chemism. In the laboratory, forces appear flitting to and fro like bees in a flower garden.

The force of cohesive attraction in elastic bodies under strain, increases directly as the space between molecules to the elastic limit, and then gives way,—as in bending a spring until it breaks.

Elastic repulsion in gases and solids, increases **inversely** as the space between molecules.

Repulsion in gases is augmented by heat, and this gives the great expansive force to steam.

Pressure is in proportion to the density of a gas, or inversely as the distance between molecules,—and may increase until it **crushes** the gas into a liquid.

Without external pressure water rapidly passes into vapor at ordinary temperatures.

In our opinion. negative electricity does not travel, but is a differing property of atoms making them unequal electrons. These are neutralized by an envelope of the positive, an immaterial substance without inertia or gravity, often displaced by friction, magnetism or chemical action. In insulated conductors, a shoving process by repulsion takes place like moving air in a tube. Electricity has

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great energy in itself, but its usual manifestation of power is much like that of a belt. Being driven, it drives other things under suitable conditions. A storage battery is wound up like a clock.

VII. WORK.

Force exerted through space progressively is called work, and is measureable in foot-pounds.

Weight may be sustained indefinitely by a dead force furnished by an animal, a block, or a post; but to lift a single pound one foot requires work, and this sort of action is measured in foot-pounds. A dead post cannot do work.

Work exhausts the agent, and has a limit in time and space. Foundation stones exerting dead force, never grow weary. What is the difference? Dead force is only pressure; work is an act progressive.

Exerted energy, or force, may be dead, aggressive or yielding; work, effective or passive.

Dead force makes no advancement. Aggressive force does work. Yielding, suffers work to be done against its own tendency or obstruction.

Draft horses do work up hill, and yield work when holding back and going down. In the latter case they do no more than a frictional wagon brake. Again, horses accomplish nothing (i. e., no work), when they **try** but can not **draw** a load. Fruitless

efforts fret and worry animals; but exertion without effect is called a dead pull, and holding back is passive.

Resistance is work to be done and has a passive nature.

To a saw the cohesion of timber furnishes passive work to be exhausted in sawing.

Passive work is frequenty accumulative as in storing up power.

The hand pressure that winds a clock is aggressively working, while the weight or spring is passive, suffering and yielding the work to be done. Passively the weight or spring gets wound up, and, as in charging a storage battery, passive energies are being prepared for aggressive service. But if the clock stops after winding, this potential energy only exerts a dead pull.

Friction is a convenient and comprehensive term covering much passive work which we count as loss or waste. Worthless heat is often generated under the head of friction.

VIII. POWER AND CONSERVATION.

Potential energy, or power, is ability to do work. It may be active, suspended, or latent.

The clock weight or spring, receives power from winding. That potential is active in the running

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clock, but suspended when the verge and pendulum are still,—the force being dead.

The muscular arm or hand has power which may be active, suspended, or latent. It is active in raising a weight; suspended in any dead pressure; and latent when there is no muscular effort or force. The power of a sleeping lion is latent.

When a man bends to lift a weight, he is gaining space for active service. We wind a clock only to get **space** and space is all we need for additional power. How simple it is when we think about it. Feet and pounds are the elements of work. Space is an essential factor of power.

An idle steamer or locomotive in perfect order with a supply of water and coal, has latent potential energy. The coal itself was **wound up** by light and heat in the primeval forest where it grew. Only tinder and a spark of fire are necessary to render the latent power effective. Pressure of steam follows heat. With heat and steam there is suspended power; with an open throttle, active.

The base of power is in material energy,—as attraction, repulsion, inertia. The superstructure is space and other favorable conditions. Water power has gravity, falling space, and a wheel.

Muscular ability grows out of food and chemical action.

Electro-magnetic power is simply magnetic attraction and repulsion **wound up** for business. The expansion of steam may be due to the centrifugal action of vibrating molecules in heat, throwing the burden on inertia. We find the very base and origin of physical forces in the creation of atomic endowments. Material energies are facts and principles of nature; but the opportunities for action ebb and flow and give power. Thus power is passed along.

The power of a clock weight partly depends on the length of the string. A long line wound up, and a deep well below the weight, would provide power for a month.

The sun winds up the world. Its heat evaporates water to fall in rain, and high water is the head of power for mills.

Organic structures are erected by light and heat. Thus wood and coal are built up and have potential energy. Organic structures tumble down in burning, and the power goes forward. Heat boils water and steam shoves a piston. The piston turns a wheel and the wheel drives a belt.

The sun has been called the source of all power; but it only produces favoring conditions for active energy, and changes that animate nature. It tips the balance of tranquility .

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Generated power may have a time limit depending on the speed of generation, as the horse-power of an engine or the applied strength of an animal at work, equal to so many foot-pounds per second, minute, or day. This is not another use of the term, but only an incidental limitation correctly called Duty.

IX. KINETICS.

Both inertive force itself and any force engaging it, are kinetic. In throwing a ball the hand exerts kinetic force; but this is mated by the inertive force of the ball in reaction. Both the active and the passive forces are kinetic.

Generally but a part of driving forces are kinetic, the balance overcoming friction. Supporting uniform motion, as in driving a train of cars at uniform speed, is not kinetic action. To win this title a force must accelerate or retard the movement of matter, thus to engage inertia which only acts under change of motion.

In retarding velocity, the forces suffer motion against their own tendency in most cases, as in back-treading a bicycle. Gravity is only resistance to a rising projectile, inertia being agressive.

Whenever uniform straight line motion has been established, there is no kinetic action; but curved motion has a constant centrifugal strain.

Kinetic Rate is that part of kinetic force which belongs to a unit mass. We find it by dividing the total kinetic action by the number of mass units. It may be entire or fractional.

Force rate is normal when it equals unity or one. This is the case with falling bodies at the earth's surface, if we ignore atmospheric resistance. A force-pound acts on a mass pound to put it in motion. In a gun the pressure of exploding powder is many times the weight of the ball expelled. This is high rate and must be expressed by a large number.

The traction on a loaded train or car over and above that required to sustain uniform motion against friction is usually very small in proportion to the weight. The division required makes the rate a minute fraction. We speak of it as low kinetic rate.

Kinetic work in foot-pounds, may also be reduced to rate units or fractions, by dividing the total kinetic work by the mass.

X. KINETIC ENERGY AS POWER.

The power of motion is the amount of work that a moving mass will do against a retarding agent slowing it down to a state of repose. In general it is the same as the kinetic work required to cause the

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motion. The waste work overcoming resistance of air or friction is not kinetic.

Doing kinetic work depends upon opposition. Motion is only relative. When a body moves unlike things around it, we say the body moves. Then it is apt to encounter other bodies, as if bludering against them, and its inertia acts. Hence the power of motion.

Repose is a state of moving in harmony,—in a world or in a boat,—no jar, no work, no dynamic effort.

Without conflict or opposition, there is no manifestation of kinetic energy. A seething mass of heat has no active power within itself; for example, take the fiery, melted metals and rocks supposed to fill the center of the earth. The heat can do nothing and can manifest no force except dead pressure against the weight of the earth shell, and this is no greater for the heat. It is not harmonic, but extraordiary heat which runs a phase of nature or an engine.

In space worlds roll on in peace and harmony; but collision would make the splinters fly. Universal heat is dead within the center of the earth. Mundane opportunity for work is found in some weak seam or volcanic pit, from which unequal, or

excess of pressure vomits forth a deluge of fiery substance; as when external cooling contracts and breaks an overlaying shell, or ages of central shrinking heaves up the crust in wrinkles like a loose garment, until it cracks and quakes the earth. Not within the thousands of millions of cubic miles of heat, but on the margin of cold, is power manifest.

Gravity alone would still the air and ocean; but when a novel condition like sun heat rising and setting, enters the arena, it disturbs repose, and sets up waves of motion. Mystic sun heat and light disturbs the peace of elements, and wave after wave of dynamic energy and power, chase each other around the globe.

New chemical reactions do the same thing. There is more or less disturbance when new motion is born. When powder burns, by its very suddenness, projectiles are hurled through space, crashing against trees, men and battlements. **Novelty** of motion is their power. Novelty of rest would do quite as much.

Were it possible for a cannon ball to absolutely stop moving on a revolving sphere, as perchance if fired westward at the earth's equator, with an apparent speed of some more than a thousand miles

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an hour, or fifteen hundred feet per second, the equatorial trees really and actually moving eastward at that rate with the earth's surface in revolution, would switch against the stationary ball and be pierced or broken in twain. Thus a mass or ball absolutely at rest, though relatively in motion, would have dynamic energy.

It is as dangerous for a moving steamer to encounter a hidden rock at rest, as to be struck by any projectile.

An elastic shooting marble A, puts B in motion and is stopped. A and B have done the same amount of work. A moved B, and B checked A. There is no absolute power distinction between relative motion and relative rest. The power resides in conditions and differentials.

XI. ACTION AND REACTION.

There is no action without opposition.

Strictly an unbalanced force is impossible and absurd. Press your fingers together. There is force. Remove one finger and what can the other do? Can it press against space? Can you pull on one end of a string and not on the other? Can cattle yoked up pull a chain taut without a load? Either action or reaction wanting, there can be no force.

It is usual, but not scientific, to speak of a force

as unbalanced when opposed only by inertia acting passively and yielding ground. But action and reaction are always equal according to Newton's Third Law. In the above case a perfect balance of force is maintained by inertia under change of motion. Inertia exerts force like a steel spring or any other energy, and is aggressive, resistive or latent, according to circumstances, and its force is real.

When railway trains collide, head on, the inertia of all the cars becomes aggressive, while the cohesion of steel and wood give way as yielding forces.

Force is often continued through masses of matter, action and reaction taking place among the molecules as along the lines of a string, or between the links of a chain. A book under pressure has force between any two pages opposed, and through all the fabric of the leaves. This sort of force travels from molecule to molecule through matter and is multiplied indefinitely and transmitted. We may consider it either collectively or distributively.

Force may be dispersed in many oblique directions, as in a tank of water under pressure; it is multiplied mechanically by the lever and other machines; but the law of equality pro and con prevails at every section. Action and reaction must be equal.

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XII. OUTLINE OF ENERGY.

Fundamental Properties of Matter.

a1—Kinds.
- b1—Attraction or Repulsion.
  - c1—Gravitative.
  - c2—Chemical.
  - c3—Molar.
    - d1—Cohesion.
    - d2—Adhesion.
  - c4—Gaseous.
  - c5—Magnetic.
  - c6—Electric.
  - c7—Caloric.

b2. Inertia.

a2—States.
- b1—Latent.
- b2—Exerted.
- b3—Dynamic.
- b4—Potential.
- b5—Kinetic.

a3—Products.
- b1—Force, or Exerted Energy.
  - c1—Dead.
  - c2—Aggressive.
  - c3—Yielding.
- b2—Work, or Dynamic Energy.
  - c1—Effective.
  - c2—Passive.
- b3—Power, or Potential Energy.
  - c1—Latent.
  - c2—Suspended.
  - c3—Active.
- b4—Duty, or Power with Time Limit.
  - c1—Horse Power.
  - c2—Man Power.
  - c3—Etc.
- b5—Motion, or Kinetic Energy.

FRIENDLY NOTES.

The Pathfinder, Washington, D. C., Jan. 18, 1908.

We have read with unalloyed interest your treatise on Dynamics of Matter, and should be glad to see you publish it in book form as a scientific work.

William C. Gould, Instructor in Physics, High School, Pontiac, Mich., Jan. 29, 1908.

I have given Mr. Slater's monograph, Dynamics of Matter, a careful study, and find it a paper of merit and interest; a treatment of a dry subject in a manner both scientific and popular, well worth the consideration of any one interested in subjects of this kind.

Horatio N. Chute, Instructor in Physical Sciences, High School, Ann Arbor, Michigan, Feb. 11, 1908. Author, Practical Physics, etc.

I have been much interested in reading your paper on the Dynamics of Matter. Although there is little to criticise in your general thought, yet you will find that modern writers on Physics will not admit the identity of force, energy and power. These terms have in recent years come to have very definite set meanings, each carrying with it an idea entirely its own and quite distinct from the others. Your modes of expression are out of the usual, but that adds to the interest of the paper.

UNIVERSITY OF MICHIGAN

Henry S. Carhart, Professor of Physics, University of Michigan, Ann Arbor, Feb. 1, 1908. Author, Elements of Physics, etc.

My own view of inertia is not precisely the prevailing one, and is more like what you have set forth. But my idea of mass has undergone some modification in the past few years. It is no longer defined as a quantity of matter, but as the measure of a body's inertia.

Professor W. L. Lodge, Department of Physics and Electrical Engineering, Michigan State Agricultural College, East Lansing, February 14, 1908.

Your manuscript on "Dynamics of Matter" has been submited to me for examination. I have read it over very carefully and with much pleasure. Sections I., on Mass and Weight, III., on Inertia and Gravitation, VII., VIII. and XI., seemed to me especially good.

You are certainly right in complaining of the poor definitions of Inertia some text books give. Professor Watson, of London, whose text is a world's standard, does not attempt to give a definition of the word at all, and simply says after quoting Newton's First Law of Motion, "This Law is also known as the Law of Inertia, since it states

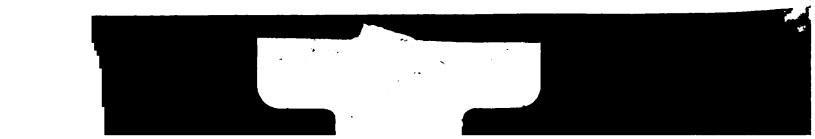
that no body is capable of altering its state of rest or of motion without the interference of some outside influence; and this fact we express in scientific language by saying that every body has Inertia."

On the whole, you have treated an interesting subject in an interesting way, and when your book is published, I will make it a point to see that a copy is placed among the books I refer my students to. I hope your book will meet with the success that it deserves.

Dr. Fred R. Gorton, Assistant Professor of Physics,
Michigan State Normal College.

Ypsilanti, Michigan, Feb. 28, 1908.

Dear Sir:—I have read the manuscript prepared by you entitled "Dynamics of Matter," and find it very interesting on account of the fact that you have stated things in a way that is unusual among writers on the subject of Physics. I cannot say that you have always adhered in the use of terms to the precise meaning that scientists have been in the habit of giving them, but it is readily seen that you have tried to use the terms whose ordinary meaning applies to the idea to be expressed. I do not regard the work as strictly elementary, but the person versed in Physics can read your contribution with considerable profit.



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